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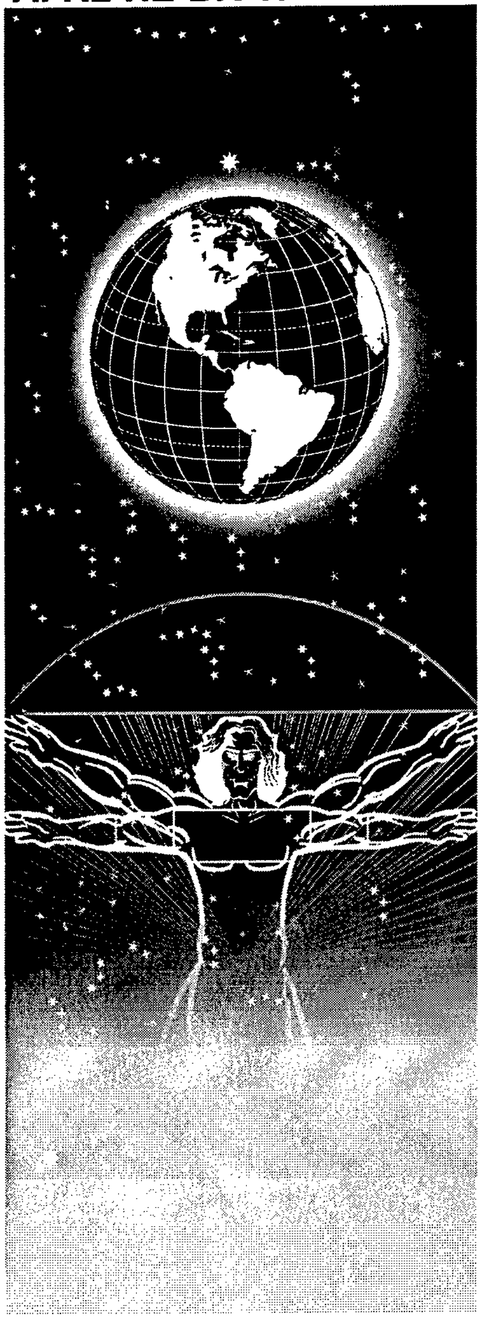

UNITED STATES AIR FORCE
RESEARCH LABORATORY

ALTITUDE AND NIGHT VISION GOGGLES

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March 1998

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public including foreign nationals.

This report has been reviewed and is approved for publication.

CARITA A. DeVILBISS
Project Scientist

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13. ABSTRACT *(Maximum 200 words)*

This paper presents the findings from a study to quantify the effect of mild hypoxia and breathing supplemental oxygen on an aircrew member's static visual acuity while using night vision goggles (NVG). In this within subjects experiment, static NVG visual acuity was measured for 15 subjects at six simulated altitude levels (i.e., ground level, 5,000, 10,000, 15,000, 18,000 and 20,000 feet). Three target contrasts (i.e., high, medium, and low) were used for each visual acuity measurement under both simulated starlight and quarter moon illumination levels. Two supplemental oxygen conditions (i.e., 100% and normal setting) were used at all altitudes and a "no" supplemental oxygen condition was used up to 10,000 feet. Overall, there was a significant decrease in average visual performance across all conditions from the equivalent of 20/44 Snellen acuity at ground level to the equivalent of 20/46 at 20,000 feet. Overall, the "100%" and "normal" oxygen conditions were not significantly different from one another. At the two lowest altitudes, the "no" supplemental oxygen condition did not differ significantly from the other two oxygen conditions. However, at the 10,000 ft. altitude, the "no" supplemental oxygen condition was significantly degraded from both the "100%" and "normal" conditions. Since this study was conducted under an existing generic altitude protocol, the results did not provide complete information on the impact on visual acuity while performing operations at 15,000 feet without supplemental oxygen, applicable to helicopter operations in the mountains. A follow-up study was recommended but not funded.

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EXECUTIVE SUMMARY

A. OBJECTIVE

The purpose of this technical paper is to provide the letter report of findings from a study to quantify the effect of mild hypoxia and breathing supplemental oxygen on an aircrew member's static visual acuity while using night vision goggles.

B. BACKGROUND

Night vision goggles (NVGs) are widely used in the helicopter community and in various fixed-wing aircraft, yet little information is available about the impact on vision with increasing altitude levels. The question from an operational perspective is whether using supplemental oxygen during NVG missions would make any difference on visual performance. Since NVGs are used in a wide variety of aircraft, both helicopters and fixed wing, this study will include several altitudes (up to 20,000 ft) and supplemental oxygen conditions (none, normal setting and 100%).

C. SCOPE

To expedite the accomplishment of this study, the existing generic protocol for altitude study was utilized. The major restriction imposed upon this study by the generic protocol was to limit altitude exposure to 10,000 ft. unless supplemental oxygen was provided. Additionally, since no oxygen prebreathing was utilized, exposure time in excess of 18,000 ft. was strictly constrained.

D. METHODOLOGY

For this study, the 25 ft. altitude chamber was modified to be light tight so that a controlled light source could be used to illuminate the target to simulate quarter moon and starlight illumination levels. This provided a realistic environment for the use of night vision goggles. Three target contrasts (i.e., high, medium, and low) were used for each visual acuity measurement under both illumination levels. Two supplemental oxygen conditions (i.e., 100% and normal setting) were used at all altitudes and a "no" supplemental oxygen condition was used up to 10,000 feet.

E. TEST DESCRIPTION

In this within subjects experiment, static NVG visual acuity was measured for fifteen subjects at six simulated altitude levels (i.e., ground level, 5000, 10000, 15000, 18000 and 20000 feet) under two illumination levels and three different target contrast levels. One subject was tested at a time, with each subject completing two chamber flights, for a total time no more than four hours. At each altitude level following a three minute acclimation period, data collection was accomplished in approximately three minutes. One illumination level was used during the ascent and the opposite illumination level was used on the descent. The order in which each subject receives the supplemental oxygen and illumination conditions was counter balanced between subjects.

F. RESULTS

Overall, there was a significant decrease in average visual performance across all conditions from the equivalent of 20/44 Snellen acuity at ground level to the equivalent of 20/46 at 20000

feet. Overall, the "100%" and "normal" oxygen conditions were not significantly different from one another. At the two lowest altitudes, the "no" supplemental oxygen condition did not differ significantly from the other two oxygen conditions. However, at the 10000 ft altitude, the "no" supplemental oxygen condition was significantly degraded from both the "100%" and "normal" conditions.

G. CONCLUSIONS

The results from this study did reveal a statistically significant decrease in performance at the 10,000 ft altitude when no supplemental oxygen was provided. After your office has determined whether this performance difference is operationally significant and whether further data is required, our team will be available for further discussions.

H. RECOMMENDATION

Since this study was conducted under an existing generic altitude protocol, the results did not provide complete information on the impact on visual acuity while performing operations at 15000 feet without supplemental oxygen, applicable to helicopter operations in the mountains. A follow-up study was recommended but not funded.

PARTMENT OF THE AIR FORCE
ARMSTRONG LABORATORY (AFMC)
BROOKS AIR FORCE BASE, TEXAS

25 Aug 94

MEMORANDUM FOR AL/CFTF JWB 25 Aug 94
AL/CFT 26 Aug 94
HQ ACC/SGPA (Lt Col Dan Flannigan)
162 Dodd Blvd STE 100
Langley AFB VA 23665-1995

FROM: AL/CFTF
2504 Gillingham Drive STE 1
Brooks AFB TX 78235-5104

SUBJECT: Letter Report - Altitude and Night Vision Goggles (NVGs) Study

1. We have completed analyzing the results from the study we conducted in response to your Human System Need 93002: Altitude Induced Vision Loss. For reference, a copy of our protocol for this study is included (Atch 1). A summary of the results is provided at Atch 2.

2. There is one outstanding question. After reviewing our protocol last fall, your office submitted a written request (Atch 3) to include a "no supplemental oxygen" condition at 15,000 ft to provide results applicable to mountain operations in helicopters. As we discussed at the time, the addition of that condition was beyond the scope of the generic protocol under which the study was designed. To expedite the study, it was decided to proceed with the original design, and determine from the results if further information is required to address the operational concerns.

3. The results from this study did reveal a statistically significant decrease in performance at the 10,000 ft altitude when no supplemental oxygen was provided. Our team will be available for further discussions, if your office determines whether this performance difference is operationally significant and further data is required.

4. If your office determines there is an operational need for further investigation, there are two points that must be brought to your attention. First, the protocol approval process will take more time since a new protocol with a higher exposure condition must be approved at the AF/SG level. Second, although we were able to conduct the last study without additional funding, we will require funds for future work to cover on-site support and operations (approximately $3,000 per day for manned flights).

5. A detailed technical report of this project is being prepared and should be complete by the end of the year. It continues to be a pleasure to work with your office. Please feel free to call either Maj Doug Apsey (DSN 240-2745) or myself (DSN 240-3521) if you would like us to pursue a follow-up study.

Carita DeVilbiss

CARITA A. DEVILBISS, PhD
Human Factors Engineer

Attachments:
1. Study Protocol
2. Summary of Results
3. HQ ACC/SGPA Ltr, 8 Oct 93

APPENDIX A

TEST PLAN: THE EFFECT OF SUPPLEMENTAL OXYGEN USE ON NIGHT VISION GOGGLE (NVG) VISUAL ACUITY

TEST PLAN: THE EFFECT OF SUPPLEMENTAL OXYGEN USE ON NIGHT VISION GOGGLE (NVG) VISUAL ACUITY

NOTE: This test plan will be conducted under the ACHE approved "Generic Protocol: Altitude Chamber Experimentation Using Human Subject Volunteers" and lies within the established limits.

1. PROJECT/TASK/WORK UNIT: 79302009 / 77552408

2. PRINCIPAL INVESTIGATORS: Maj Douglas A. Apsey
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4. MEDICAL CONSULTANT: Capt Darlinda Grice
Base Flight Surgeon, USAF Clinic
Brooks AFB, TX

5. CONTRACTOR: none

6. FACILITY: Altitude Chamber C
Building 160, Brooks AFB, TX

7. OBJECTIVE: To quantify the effect of mild hypoxia and breathing supplemental oxygen on an aircrew member's visual acuity while using night vision goggles (NVGs) at various altitudes with different illumination and target contrast levels.

8. BACKGROUND AND RELEVANCE: NVGs are widely used in the helicopter community and in various fixed wing aircraft, yet little information is available about the impact on vision with increasing altitude levels. This study is in response to a Human System Need submitted by HQ ACC/SGPA and HQ AFSOC/SEF and prioritized by the HQ AFMOA/SGP aerospace medicine panel. The question from an operational perspective is

whether using supplemental oxygen during NVG missions would make any difference on visual performance.

a. Unaided Night Vision. Much is known about the interaction between the unaided visual system, altitude and decreased illumination. In a literature review on the effects of low oxygen tensions on visual performance, Dyer (1988) reported hypoxia produces reduction in differential visual sensitivity with the greatest reduction when illumination was lowest. Traditional guidance for military aviation is that the use of oxygen, even at low pressure altitudes, can be very important at night (Miller and Tredici, 1992).

b. Aided Night Vision. Third generation (Gen III) image intensification technology in current NVGs provide the user with a monochromatic image with a 30°-40° field of view and a display luminance around 1-2 millilamberts, depending upon the device design. With this level of image luminance the aviator is operating with aided night vision in the mesopic range throughout the operational range of NVGs while unaided night vision is in the scotopic range.

c. Gen II NVGs and Altitude. In one study, Leber et al (1986) used second generation (Gen II) goggles to investigate the impact of altitude on aided night vision at simulated altitudes of 7, 10, and 13 thousand feet above sea level. The dependent variable was the threshold light intensity, as controlled with neutral density filters, at which the subjects could just see a visual target. Four visual targets (14, 7, 3.5, and 1.75 cycles per degree) were used. Results showed hypoxia differentially affected unaided and NVG-aided visual performance. Unaided visual performance was degraded by the lack of oxygen to a much greater degree than was aided visual performance.

d. Gen III NVGs and Altitude. Results from the study with the older Gen II goggles do not directly extrapolate to current Gen III goggles. First, Gen III NVGs operate at lower illumination levels, e.g., down to overcast starlight (Kotulak and Rash, 1992). Second, Gen III NVGs provide better image quality with the best Snellen acuity reported as 20/50 for Gen II and 20/40 for Gen III. The capability to resolve finer detail at lower illumination could be more impacted by hypoxic conditions.

e. Altitude and Supplemental Oxygen. Since NVGs are used in a wide variety of aircraft, both helicopters and fixed wing, this study will include several altitudes (up to 20,000 ft) and supplemental oxygen conditions (none, normal setting and 100%).

f. Illumination and Contrast. In evaluating the impact of altitude and supplemental oxygen on NVG performance, it is important to remember that NVGs are used under a variety of environmental conditions. Both optimal and suboptimal illumination levels should be used as well as high, medium, and low contrast targets since NVG visual acuity falls off more rapidly (see Figure 1) for low contrast targets than for high contrast under degrading conditions (Kotulak and Rash, 1992).

9. IMPACT STATEMENT: Knowledge of visual effects induced in aircrew using NVGs when exposed to increased altitude is very important in maintaining maximum aircrew safety and mission effectiveness.

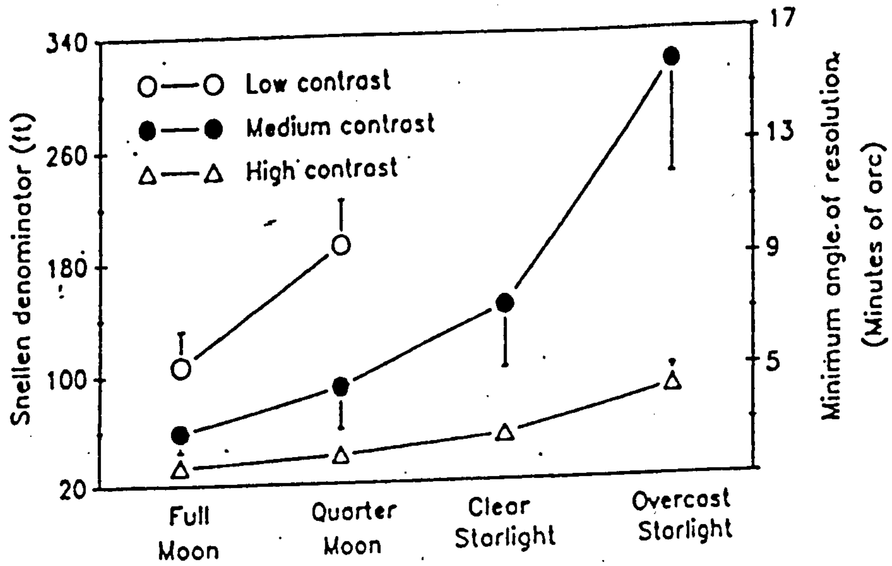

Figure 1. Visual acuity as a function of night sky condition and target contrast with generation III night vision goggles (Source: Kotulak and Rash, 1992).

10. EXPERIMENTAL PLAN:

a. Facility. Armstrong Laboratory's altitude chamber C will be used for this experiment. Modifications (i.e., window covering, light shields, and reflection guards) will be made to the chamber to provide controlled internal light levels.

b. Equipment. The following special equipment will be used for this experiment.

(1) Goggles. Two operational quality Gen-III ANVIS-6 (aviators night vision imaging system) night vision goggles (NVGs) will be used for data collection. Inside observers will also be provided with an NVG. Prior to data collection, each ANVIS will be evaluated to ensure optimal performance.

(2) Illumination. The selected illumination levels will be provided by the moon illumination source developed at AL/CFHV and measured with the Photo Research 1530A radiometer.

(3) Target. The visual target used during data collection will contain high resolution square wave grating patterns similar to the standard AF NVG Resolution Chart. High, medium, and low contrast levels of the chart will be available.

c. Subjects. The twenty subjects will be volunteer active duty military personnel who have been qualified as members of the Generic Altitude Subject Panel. All subjects will receive instruction in NVG adjustment procedures, since subjects are not required to have prior NVG experience.

d. Key Personnel. During each chamber flight, a principal investigator, an aerospace physiologist, a medical monitor, and an inside observer will perform duties in accordance with their responsibilities specified in the generic protocol (para 9b).

e. Experimental Design. This will be a two factor, within subjects, repeated measures study at two illumination levels. Since goggle performance is known to degrade with decreased illumination and target contrast, a separate analysis of variance procedure with the following variables will be computed for each illumination and target contrast combination to determine if there is any statistically significant difference in visual performance.

(1) Independent Variables. Two independent variables, altitude and oxygen will be used for each level of illumination and target contrast (see Figure 2). The following constraints are imposed to ensure this test is within the basic limits of the approved generic altitude protocol. Results from this study will be evaluated to determine if conditions that will require a waiver should be investigated.

(a) Altitude. Data will be collected at six altitude levels (i.e., ground, 5, 10, 15, 18 and 20 thousand feet). Since subjects will not have pre-breathed, exposure above 18 thousand feet is limited to a maximum of fifteen minutes (Table II, generic protocol). Therefore, data collection at 20 thousand feet will be terminated if necessary to stay within this requirement.

(b) Oxygen. Between ground level and 10,000 feet, three supplemental oxygen conditions (none, normal setting, and 100%) will be used. Above 10,000 feet, only supplemental oxygen at the normal setting or 100% will be used (Table I, generic protocol).

(c) Acclimation. To allow physiological stabilization to each condition, a three minute acclimation period will be used for each altitude and oxygen combination. Additionally, all subjects will dark adapt for fifteen minutes prior to data collection.

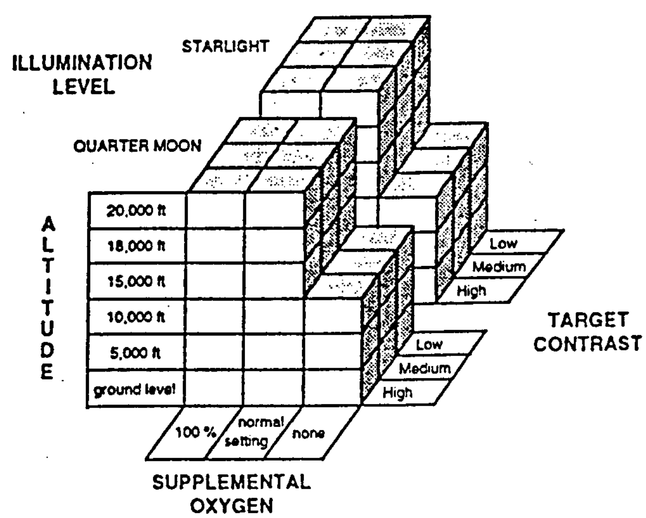

Figure 2. Independent variables used in the experimental design at each level of illumination.

(2) Dependent Variable. The dependent measure will be the NVG visual acuity measured with the standard NVG Resolution Chart as follows. The subject will be shown the 3 X 3 chart and asked to "read" the chart (left-to-right, top-to-bottom) by stating the grating orientation (i.e., "horizontal," "vertical," or "can't resolve"). The orientation of the chart will be changed, and the process repeated for a total of four times. A probability of detection will be computed by counting the number of correct identifications of each grating (i.e., ranging from 100%--"4 of 4" to 0%--"0 of 4"). The 75% detection level will be the acuity measure.

f. Procedure . The general procedure is as follows:

(1) Enrollment. Before being accepted for participation in this study, subjects will receive a full eye examination, including dark adaptometry. This examination will ensure each subject's vision is corrected to at least 20/20 and that they have no ocular pathology that may affect their night vision. All subjects will complete a general background questionnaire that will include their tobacco use history, and study results will be analyzed to identify any correlation between tobacco use and degraded night vision. Each subject will read and sign the Informed Consent Form before participating.

(2) NVG Training. No prior NVG experience is required. All subjects will receive adjustment training and practice. Baseline NVG visual acuity will be measured upon completion of the training to ensure each subject is capable of adjusting the NVGs to obtain their best visual acuity. Subjects who cannot obtain at least 20/40 visual acuity will not participate in this study,

(3) Chamber Flights. One subject will be tested at a time. Each subject will have two chamber flights, with the total time no more than four hours (see Figure 3). At each altitude level, there will be a three minute acclimation period and approximately three minutes of data collection. After completing the first data collection at the peak altitude, the illumination level will be changed and the process will be repeated before beginning the descent. As indicated, the subject will be under the same illumination and supplemental oxygen condition during specific segments of each flight. The order in which each subject receives the supplemental oxygen and illumination conditions will be counter balanced between subjects.

11. DATES: Data collection will be conducted on Monday and Tuesday, starting in Jan 94.

12. MEDICAL RISK ANALYSIS: This test is within the stated limits of the approved Generic Protocol and will use only subjects from that Altitude Panel. Therefore, all subjects will have been informed of potential hazards and will be familiar with the altitude chamber environment and oxygen breathing equipment. Pre-breathing is not necessary since exposure to altitudes greater than 18,000 feet will be less than 15 per chamber flight .

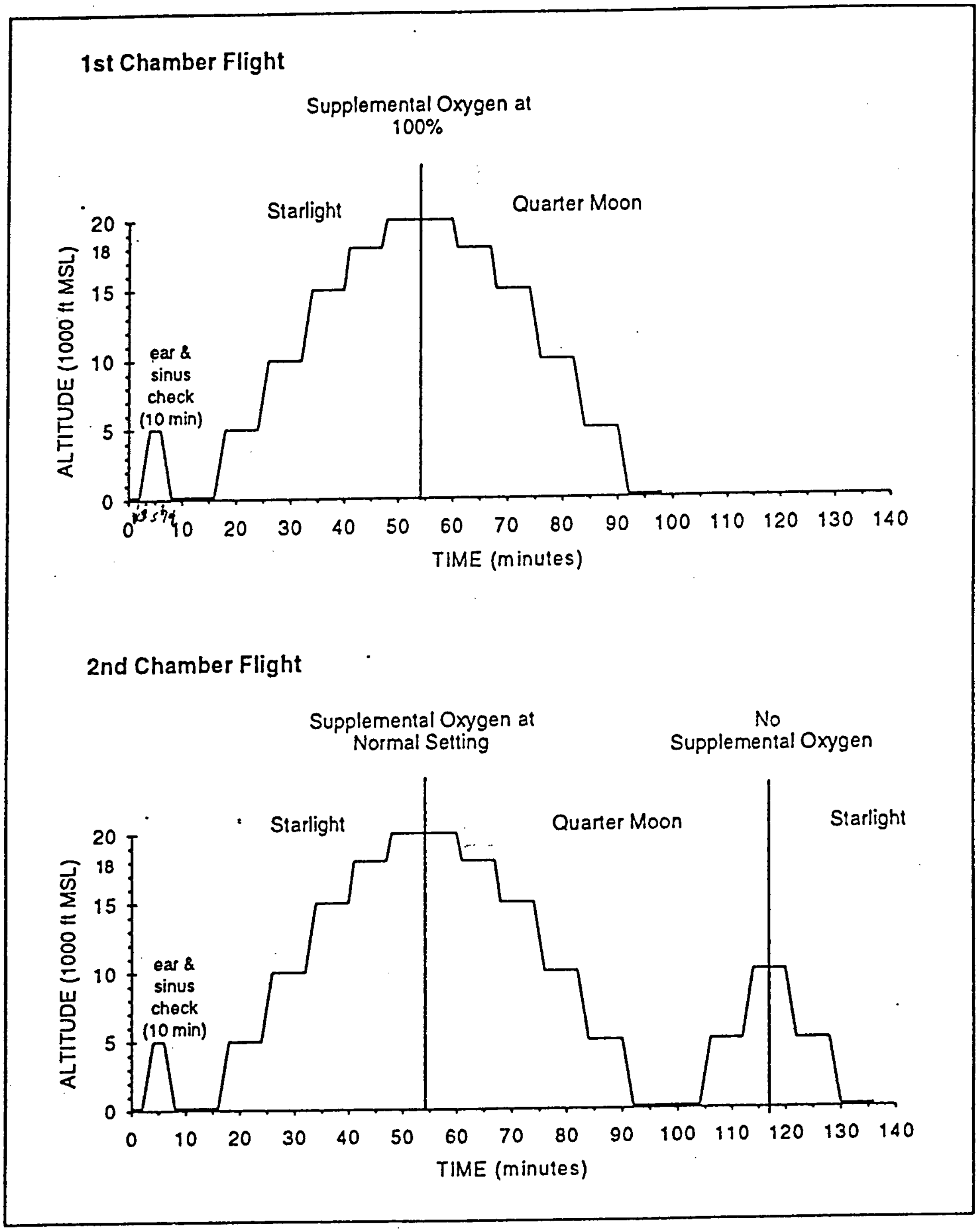

Figure 3. Chamber flight profiles with one subject per flight and a climb/dive rate of 2,500 ft per minute.

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14. ATTACHMENT:

Informed Consent Statement.

CARITA A. DEVILBISS, PhD
Human Factors Engineer

DOUGLAS A. APSEY, Major, USAF, BSC
Research Optometrist

APPENDIX B

RESULTS

RESULTS

NOTE: The following terms are used in this discussion:

cycle: a set of bars on the target consisting of one black and one white bar

cpd: cycles per degree of visual angle

spatial frequency: overall resolution of a visual target, expressed as cpd. Higher spatial frequency (i.e., more cycles per degree) indicates higher resolution.

performance: the average spatial frequency that the subject correctly identified in at least 75% of the times each target was presented.

1. Altitude. Across all altitudes, there was a statistically significant decrease in performance as altitude increased.

a. Overall average performance decreased from correctly identifying a visual target with a spatial frequency of 13.8 cpd (equivalent to 20/43.6 Snellen visual acuity) at ground level to correctly identifying a target with 13.1 cpd (equivalent to 20/45.7) at 20,000 ft.

b. Two within subjects four factor analysis of variance (ANOVA) procedures were used to analyze this data set. The first analysis (ANOVA #1) evaluated all four factors (supplemental oxygen, altitude, illumination, and contrast) across all three supplemental oxygen conditions at the lower three altitudes. The second procedure (ANOVA #2) evaluated all four factors across two supplemental oxygen conditions (i.e., "100%" and "normal") at all six altitudes. The average performance by altitude from these two ANOVAs are presented below. Averages grouped together with the same letter (i.e., "a", "b", or "c") are not significantly different from one another.

ANOVA #1
(3 supplemental oxygen conditions)

Altitude	Avg. Spatial Frequency	
ground	13.759	a
5,000 ft	13.616	a
10,000 ft	13.462	b

ANOVA #2
(2 supplemental oxygen conditions)

Altitude	Avg. Spatial Frequency	
ground	13.798	a
5,000 ft	13.707	a
10,000 ft	13.725	a
15,000 ft	13.451	b
18,000 ft	13.465	b
20,000 ft	13.126	c

2. Altitude by Oxygen Interaction (Figure 1). In ANOVA #1, when all three oxygen conditions were analyzed at the three lower altitudes, there was a significant interaction between

altitude and the oxygen level. Interpreting these first two results together, the following statements can be made:

a. Overall, the "100%" and "normal" oxygen conditions did not statistically differ from one another.

b. At the lower two altitudes (ground and 5,000 ft) there were no significant differences in performance between the three oxygen conditions, i.e., "100%," "normal," and "no supplemental" oxygen conditions.

c. At the 10,000 ft altitude, the performance with "none" supplemental oxygen was significantly worse than the performance at the other two oxygen conditions.

3. Oxygen by Contrast Interaction (Figure 2). In ANOVA #1, when all three oxygen conditions were analyzed at the lower altitudes, there was a significant interaction between the supplemental oxygen condition and the target contrast level.

a. With a high contrast target, performance was different among all three supplemental oxygen conditions, with "100%" having the best performance and "none" having the poorest performance.

b. When the medium contrast target was used, "100%" and "normal" supplemental oxygen conditions performed equally better than with the "none" condition.

c. There were no differences between performance attributed to the supplemental oxygen condition when the low contrast target was used.

4. Illumination and Contrast (Figure 3). As known a priori, performance was significantly better under quarter moon illumination than it was under starlight and significantly decreased with decreasing contrast in the target.

5. Four-Way Interaction (Figure 4). Although the four-way interaction (i.e., illumination X contrast X altitude X oxygen) was not statistically significant, this figure is presented to illustrate how the subjects' performance varied across all conditions. All of the statistically significant results discussed above can be seen in this composite figure.

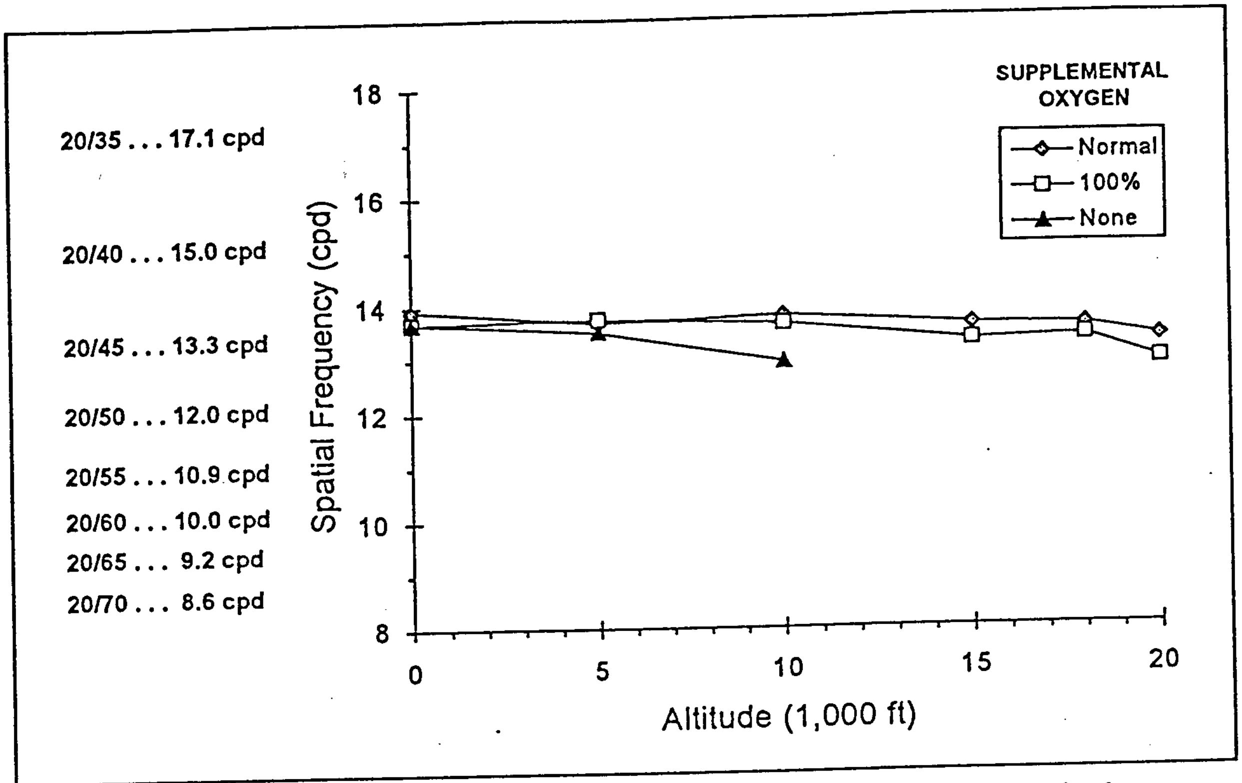

FIGURE 1. There was a statistically significant decrease in performance as altitude increased. The "normal" and "100%" supplemental oxygen conditions were not significantly different from one another. However, at 10,000 ft when no supplemental oxygen was used (i.e., "none") performance was significantly poorer than with either "100%" or "normal" supplemental oxygen. At the lower altitudes, ground level or 5,000 ft, all three conditions had the same level of performance. Each symbol represents the average of 90 data points (i.e., 15 subjects across 2 illuminations and 3 contrast levels).

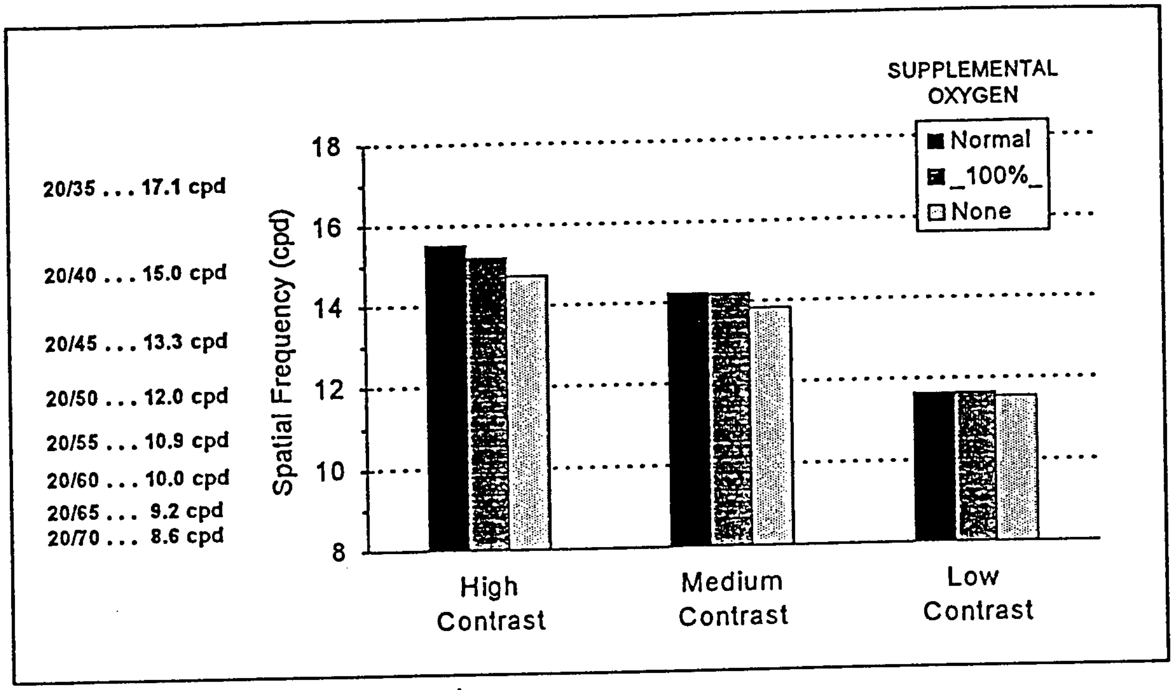

FIGURE 2. When all three supplemental oxygen conditions were used at the lower altitude levels (i.e., 10,000 ft and below), there was a significant interaction between supplemental oxygen and target contrast level. Each histogram represents the average of 90 data points (i.e, 15 subjects across 2 illumination levels and 3 altitudes).

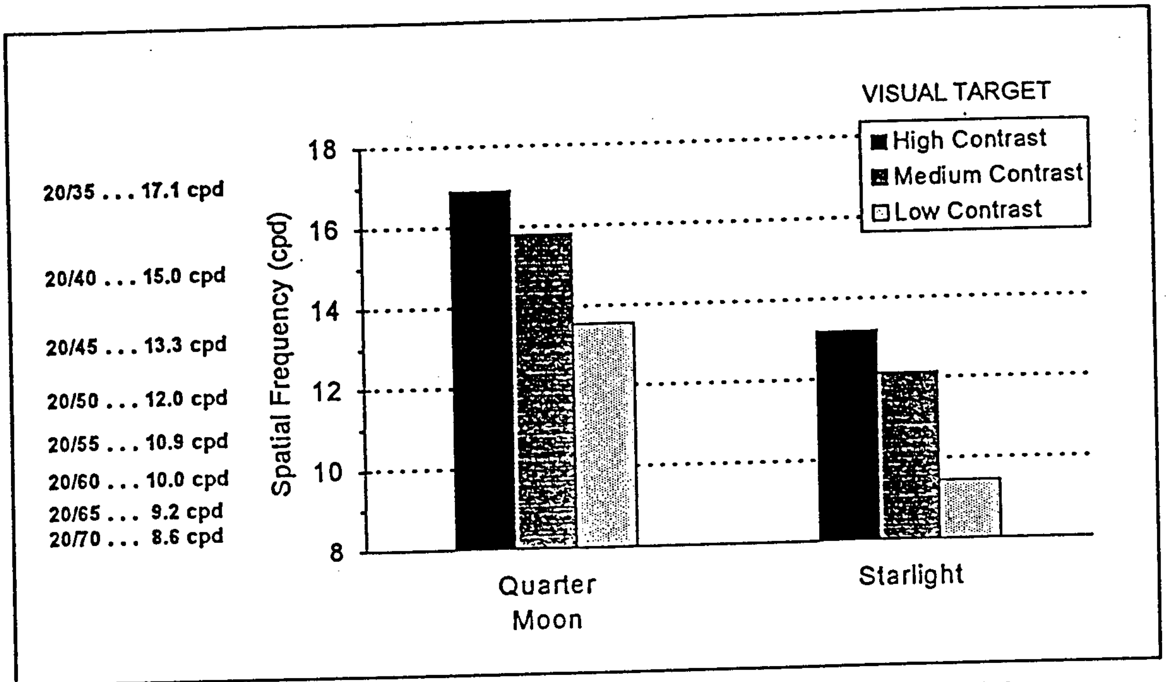

FIGURE 3. As expected, performance was significantly different under different illumination conditions and target contrast levels. Each histogram represents an average across 225 data points (i.e., 15 subjects across 1 oxygen condition with 3 altitudes and 2 oxygen conditions with 6 altitudes).

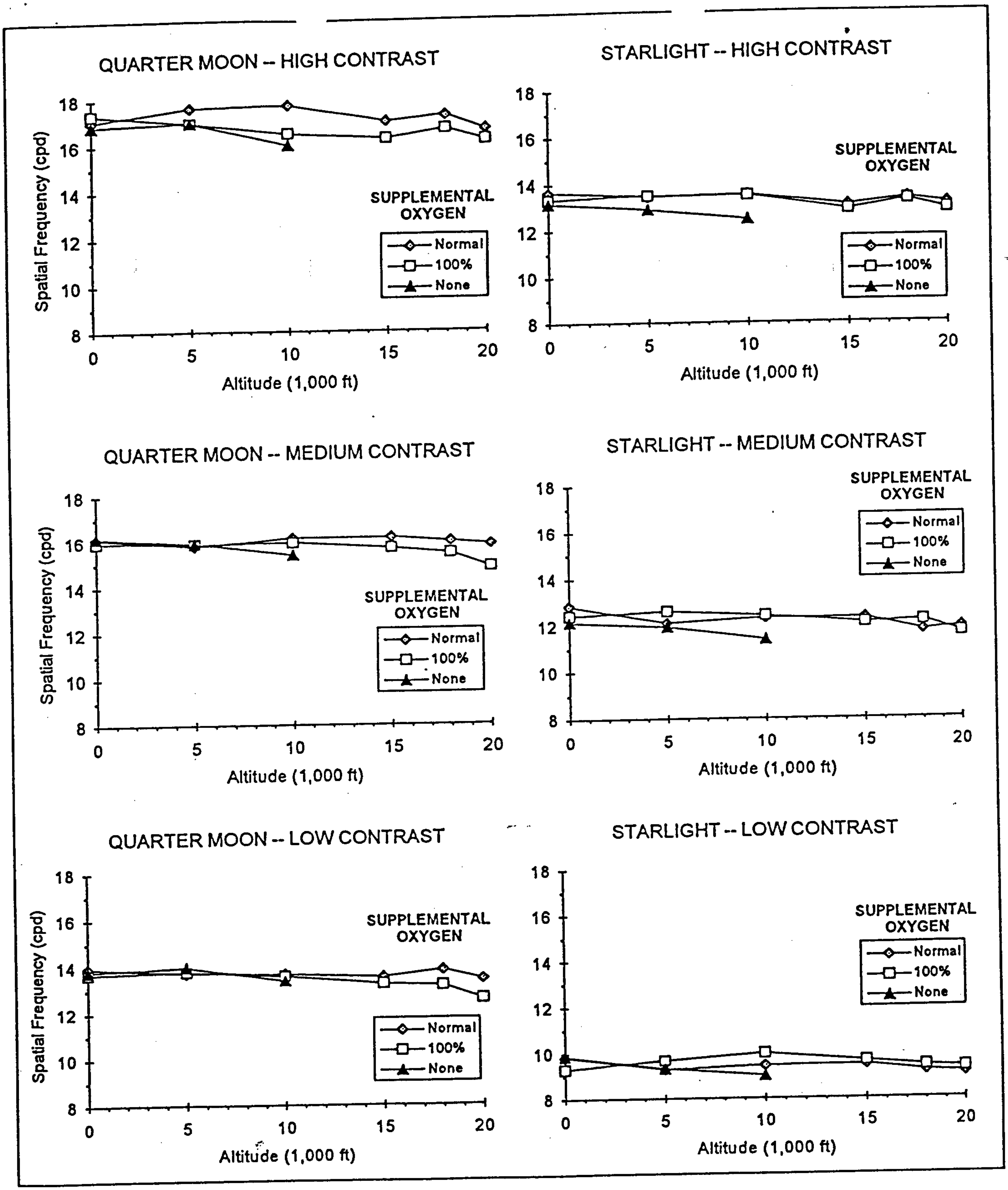

FIGURE 4. Summary of performance for each of the illumination levels, target contrast levels, and all altitudes. Each symbol represents the average performance across the 15 subjects.